Multi-spin galaxies on the 6-m telescope: forty-years history of researches

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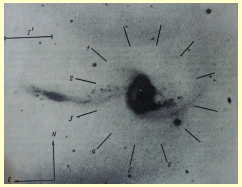
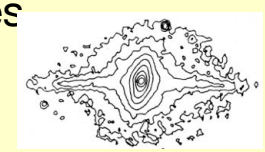
6-m telescope and multi-spin systems

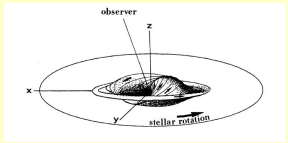
Interacting galaxies

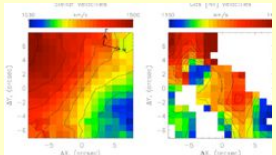




polar rings

Inner polar discs





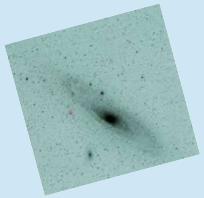
counter-rotation

Accretion & off-plane gas

New discoveries

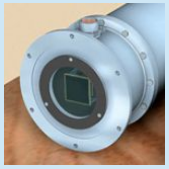
Observational techniques

Photographic plates

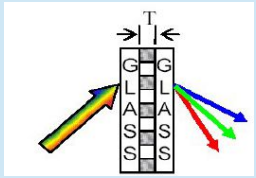


IPCS

CCD

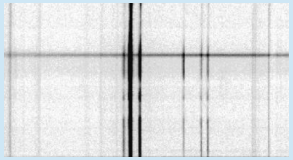


VPHG



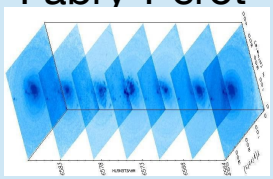
3D spectroscopy:

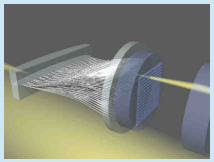
image intensifiers



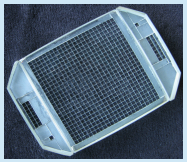
long-slitl

Fabry-Perot





integral-field

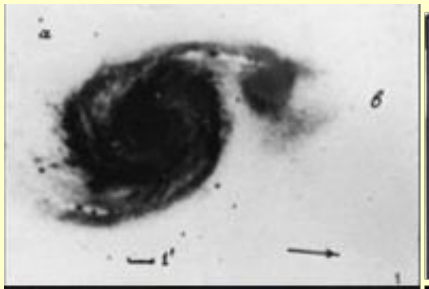


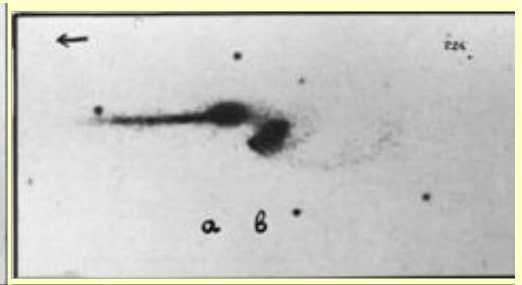
“Journeys to Arkhyz” in 1928-1929

Рис. 37. Сбор геологических образцов.

Борис Александрович Воронцов-Вельяминов.
Фотография конца 20-х годов.

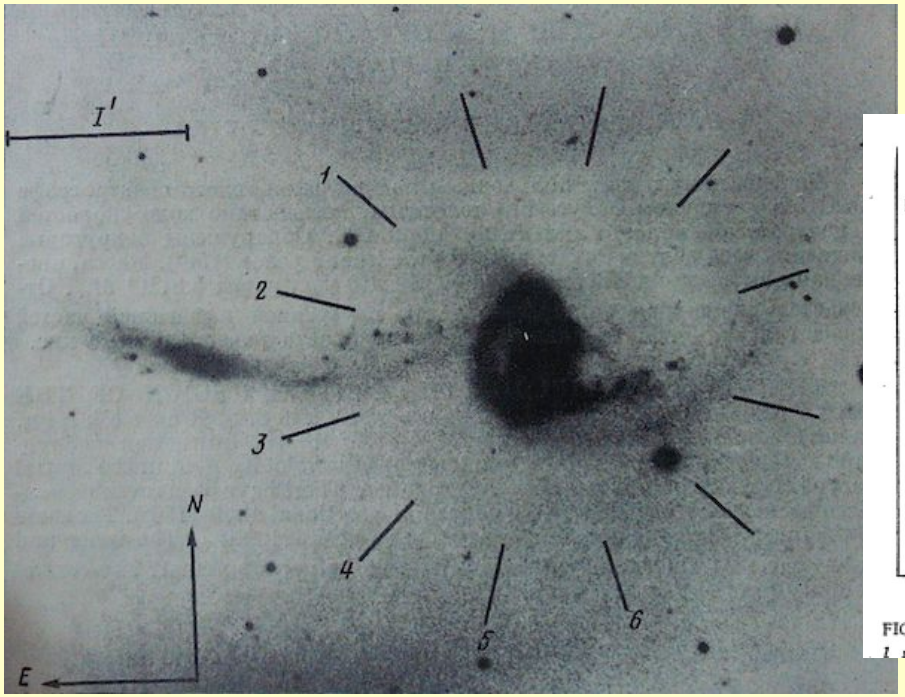
Vorontsov-Velyaminov, B. A.
“Atlas of Interacting Galaxies” (1956, 1977)





70-80th: gas kinematics with long-slit spectroscopy

Mrk 538



Afanasev & Rassokhin (1982):
"... the inner and outer parts of the disk are not coplanar"

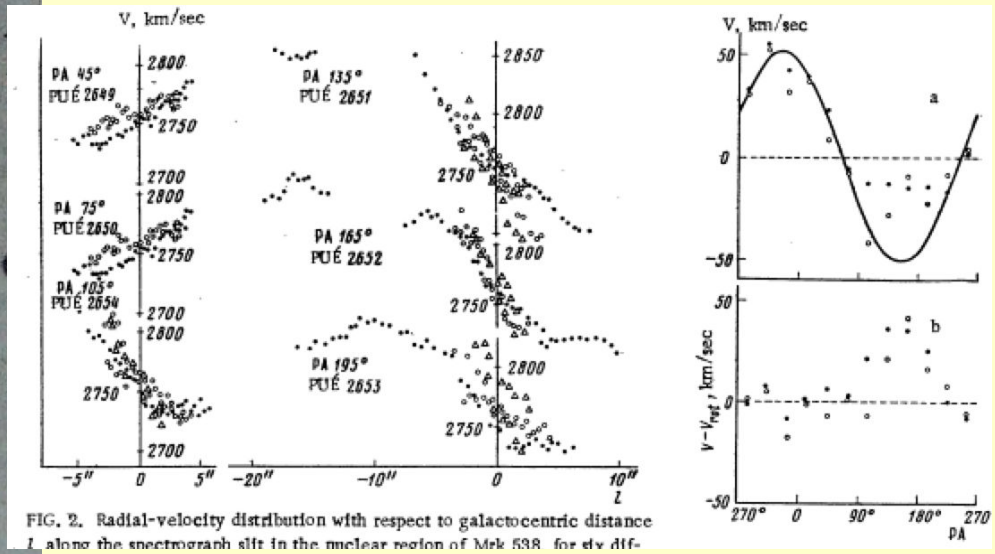


FIG. 2. Radial-velocity distribution with respect to galactocentric distance l along the spectrograph slit in the nuclear region of Mrk 538, for six dif-

Rotation of the inner regions of the spiral galaxies (Afanasiev, Burenkov, Zasov & Silchenko 1988-1992):
- detection of non-circular motions, presents of inner bars, etc...

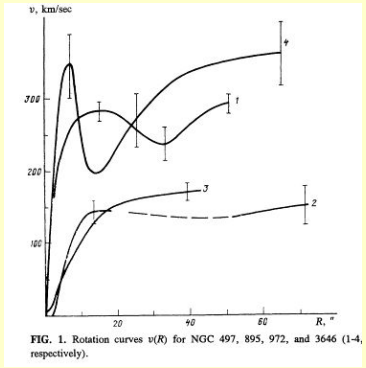
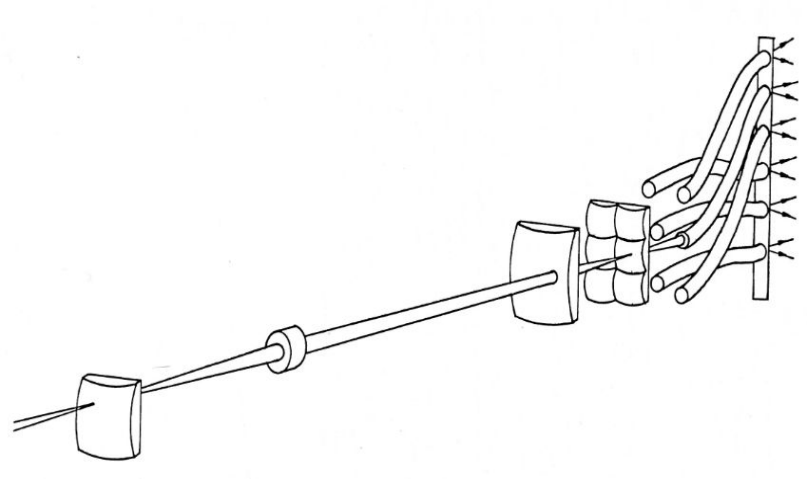


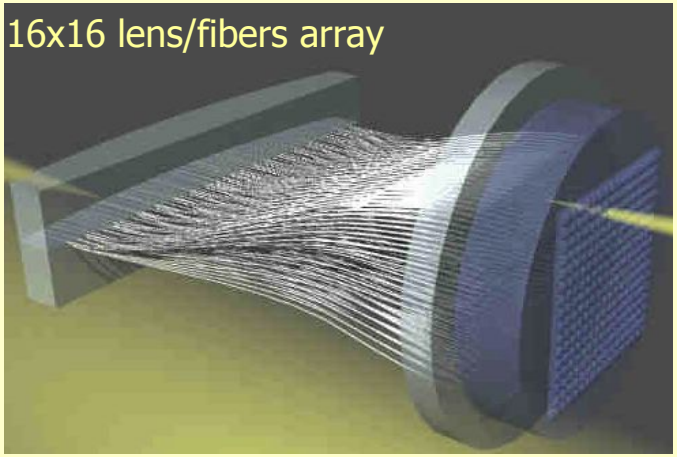
FIG. 1. Rotation curves v(R) for NGC 497, 895, 972, and 3646 (1-4, respectively).

80th: Integral-field spectroscopy is coming...



``An Integral Field Spectrograph (IFS) for Large Telescopes''
Georges Courtès 1982 (Proceedings of IAU Colloq. 67, held in Zelenchukskaya, USSR)

Multi Pupil Fiber Spectrograph (MPFS):
Afanasiev et al. (1990, 2001)



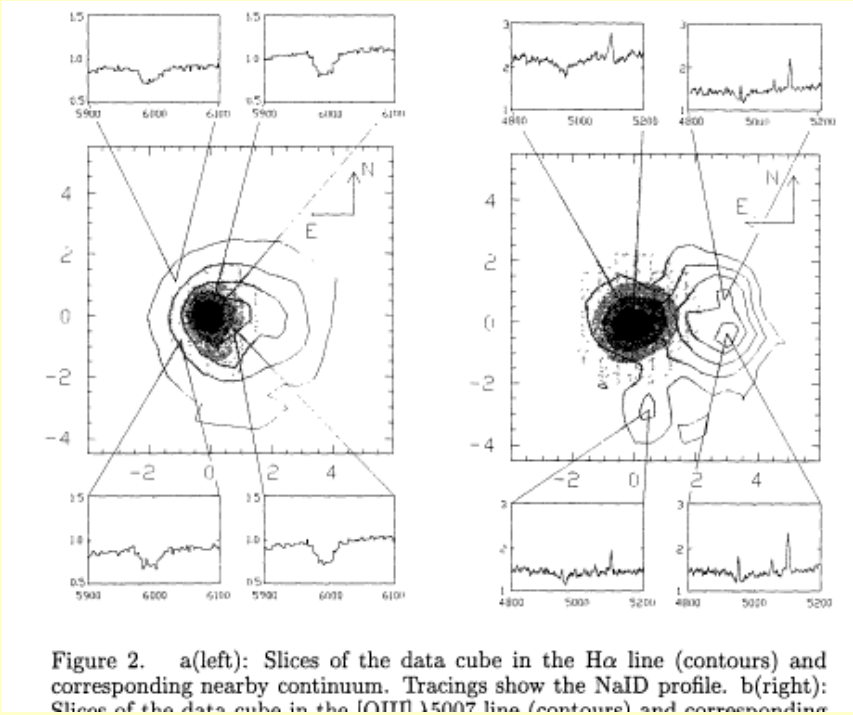


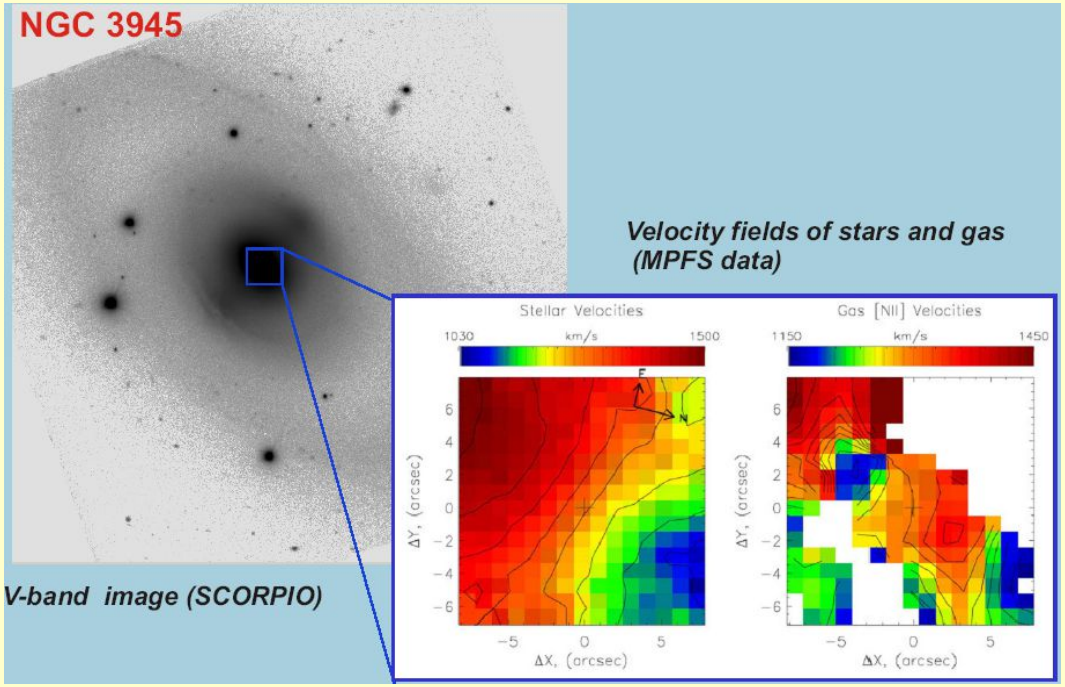
Figure 2. a(left): Slices of the data cube in the Hα line (contours) and corresponding nearby continuum. Tracings show the NaID profile. b(right): Slices of the data cube in the [OIII] λ5007 line (contours) and corresponding

Rafanelli et al. (2000)

Kinematical decoupled structures with MPFS

- **Ionized gas in AGN, stellar kinematics of mergers** (Afanasiev+01, Rafanelli+00, Ciroi+03,05, Smirnova+05,10)
- **Discovery chemically decoupled nuclei in disk galaxies!** (Sil'chenko, Afanasiev & Vlasyuk 92)

Nuclear polar rings (Sil'chenko +97, Sil'chenko & Afanasiev +04, Moiseev + 04)



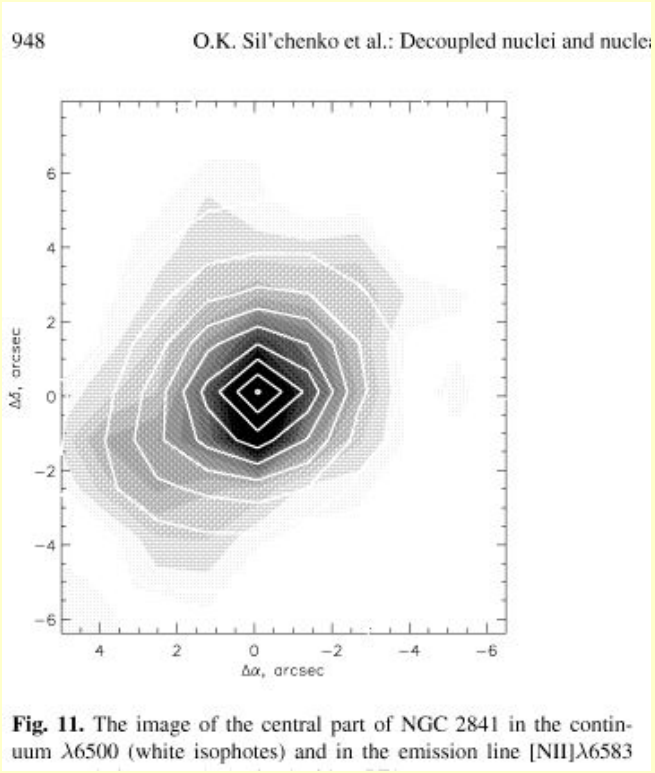
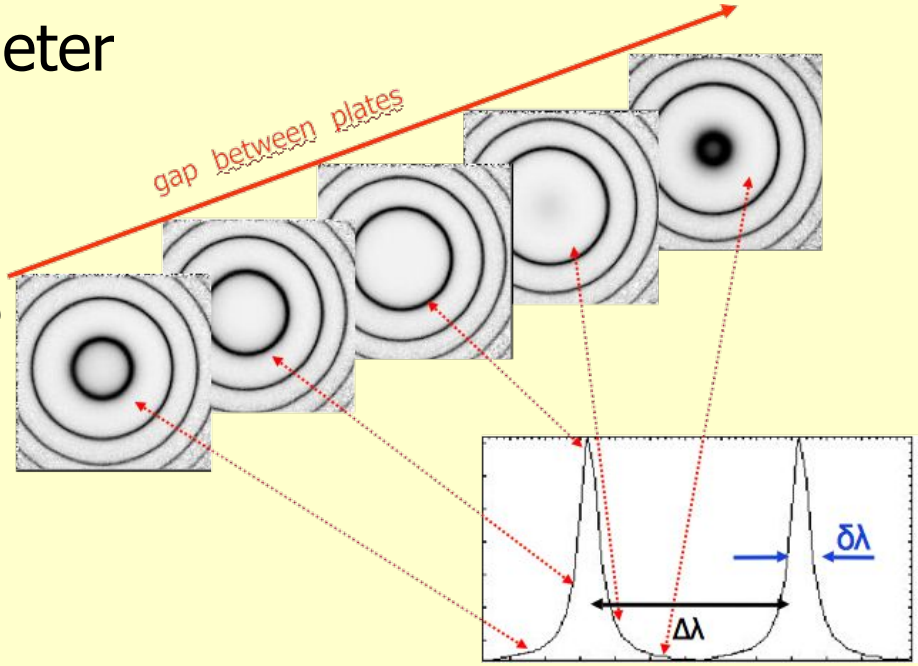


Fig. 11. The image of the central part of NGC 2841 in the continuum λ6500 (white isophotes) and in the emission line [NII]λ6583

Scanning Fabry-Perot interferometer

Boulesteix et al. (1982):
Two dimensional interferometric photon counting observations with the 6m telescope
> a progress in names: now "3D" instead "2D"! :)



Plana + 1996:
Two kinematicallly decoupled gas in possibly located in different basic planes of the ellipsoids in NGC 1052 and NGC 7332

<= talk by Alessandro Pizzella yesterday!

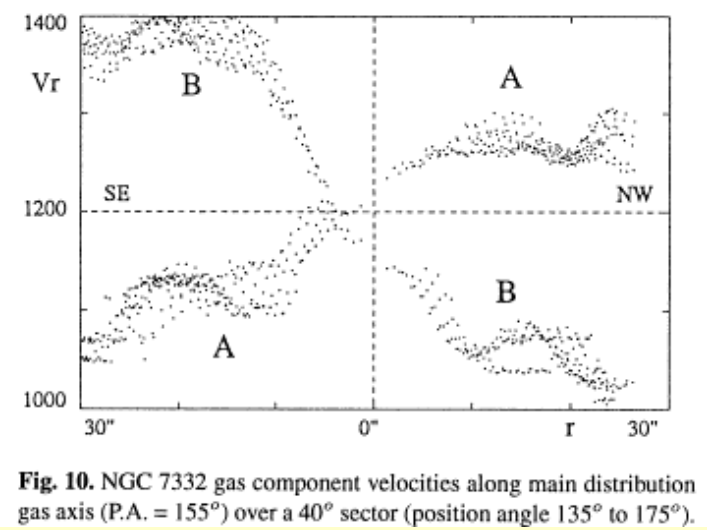


Fig. 10. NGC 7332 gas component velocities along main distribution gas axis (P.A. = 155°) over a 40° sector (position angle 135° to 175°).

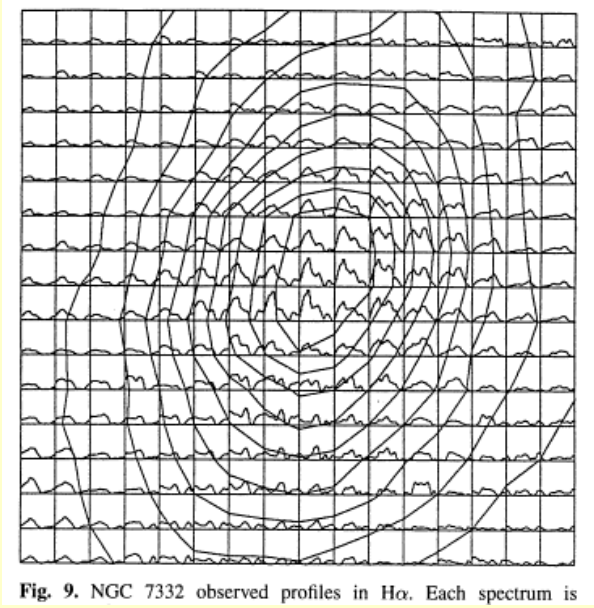


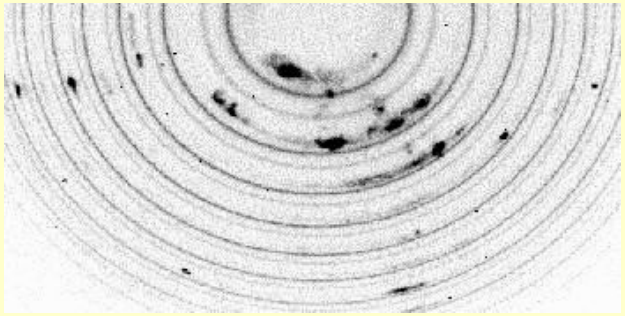
Fig. 9. NGC 7332 observed profiles in Hα. Each spectrum is

Scanning Fabry-Perot interferometer in SCORPIO

Spectral **C**amera with **O**ptical **R**educer for **P**hotometric and **I**nterferometric **O**bservations

SCORPIO

SCORPIO-2



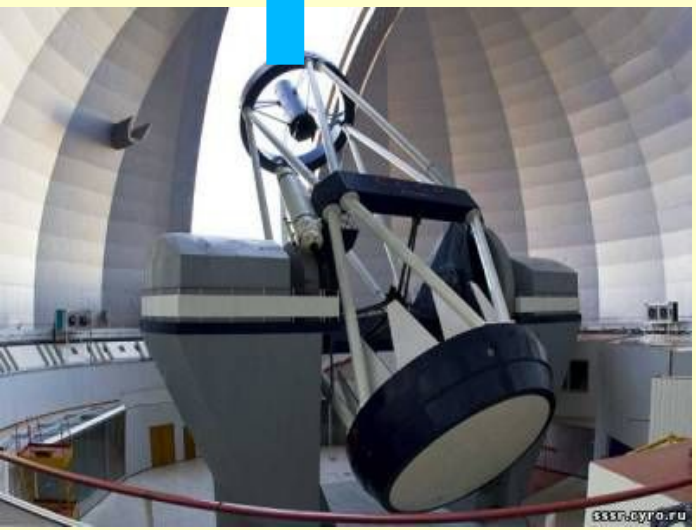
FPI in SCORPIO/SCORPIO-2 (Afanasiev & Moiseev, 2005/2011)

Field of view: 6.1 x 6.1 arcmin

Spectral range: Hα, [SII] 6717, [OIII]5007 lines

Spatial sampling: 0.35-0.70 arcsec/px

Spectral resolution: R=4000-16000

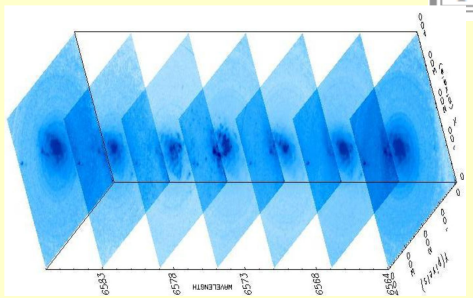


Piezoelctric FPI

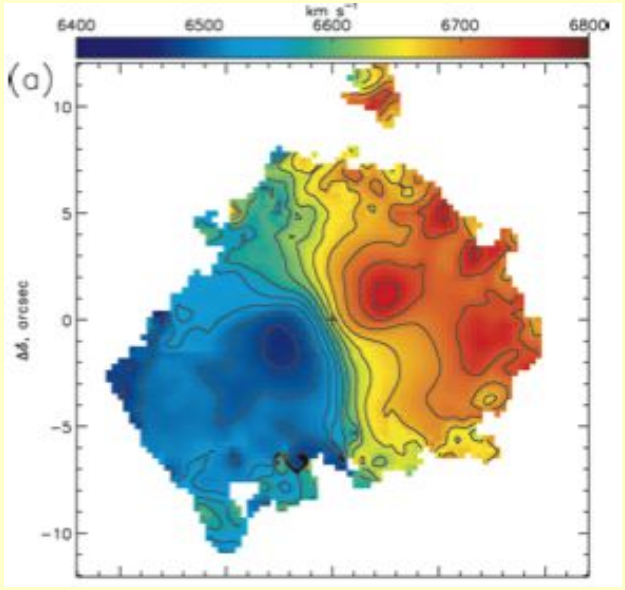
IC Optical Systems Ltd.

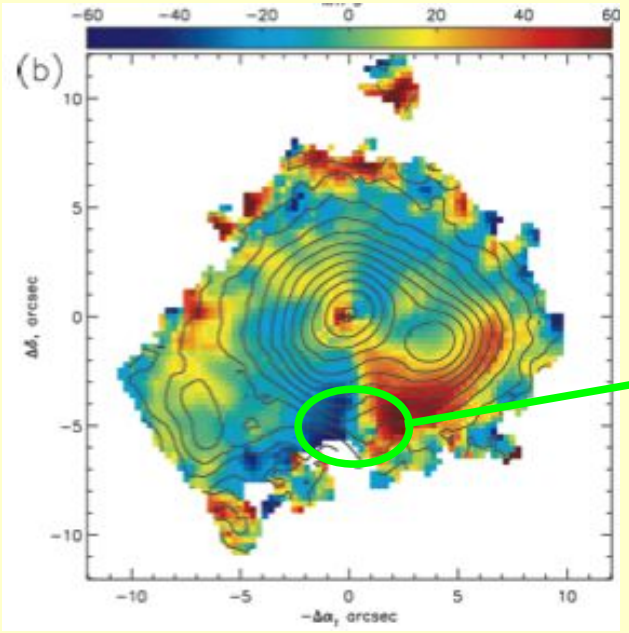
UK

	IFP186	IFP501	IFP751
Order	186	501	751
Interfringe	35 A	13 A	8.7 A
Sp. resolution	1.7 A	0.8A	0.4A



FPI + MPFS: a low-density circumnuclear cavern in Mrk 334





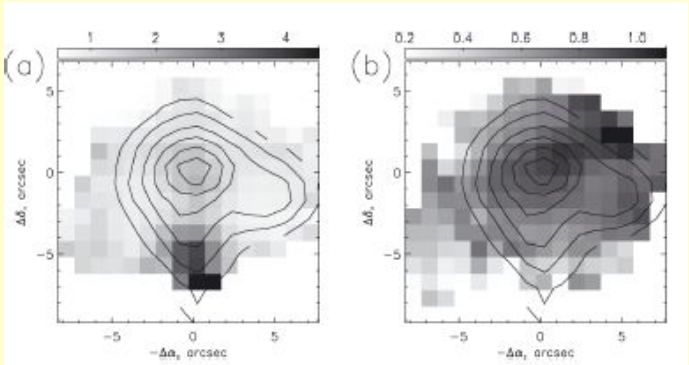
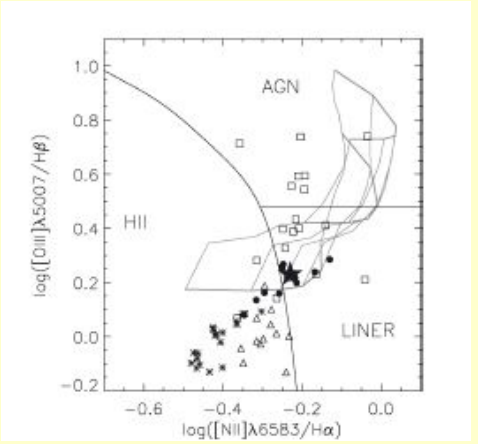


Figure 8. Map of the [O III]λ5007/Hβ (a) and [S II]λ6731/6717 (b) line



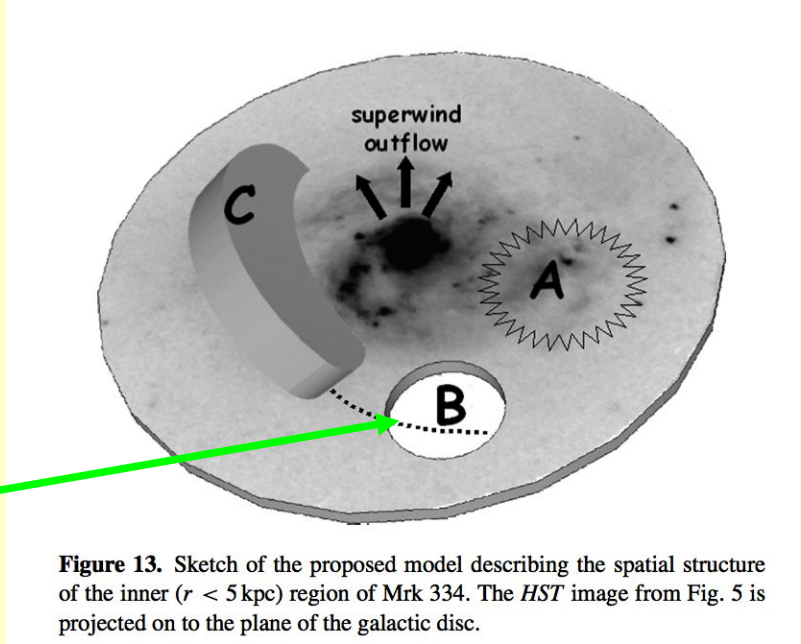


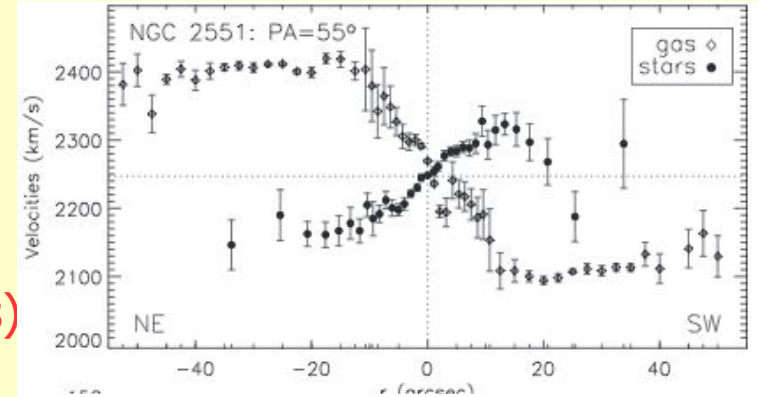
Figure 13. Sketch of the proposed model describing the spatial structure of the inner ($r < 5$ kpc) region of Mrk 334. The *HST* image from Fig. 5 is projected on to the plane of the galactic disc.

Smirnova & Moiseev (2010)

Global counter-rotation

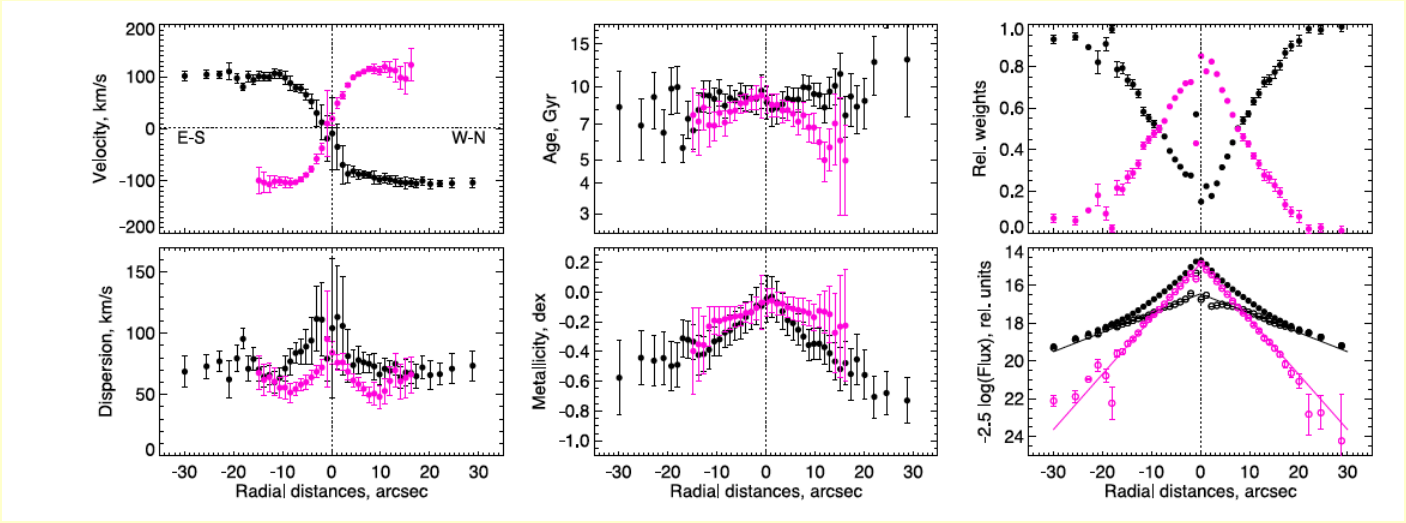
Counter-rotating discs: (see review by Corsini 14):
NGC 4546 (Bettoni + 91)
NGC 2551, NGC 5631 (Sil'chenko + 09)
NGC 4550 (Coccato+13, Johnston +13)

New statistics (6-m BTA and SALT 10-m telescopes)
extended ionized-gas discs are found in
58-72% of the isolated S0 (Katkov + 14, 15)



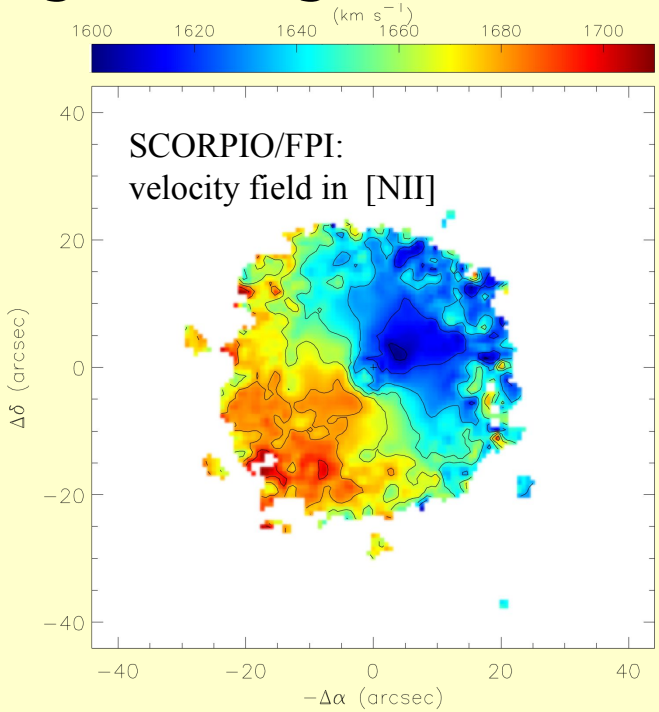
Sil'chenko, Moiseev & Afanasiev (2009)

Stellar counter-rotation (Katkov + 16): the sattelite merger as a potential mechanism of the counter-rotating component formation in NNGC 448

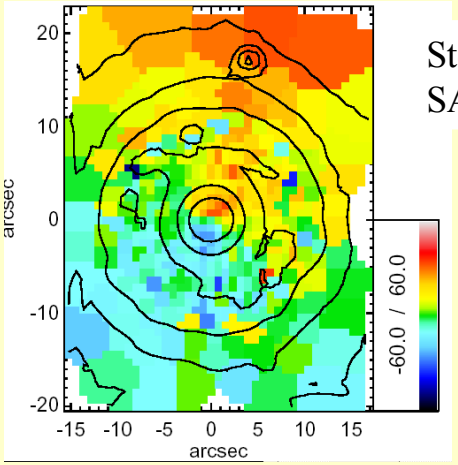


<= talk by Ivan Katkov

NGC 7742: an accretion origin of ring in unbarred galaxy



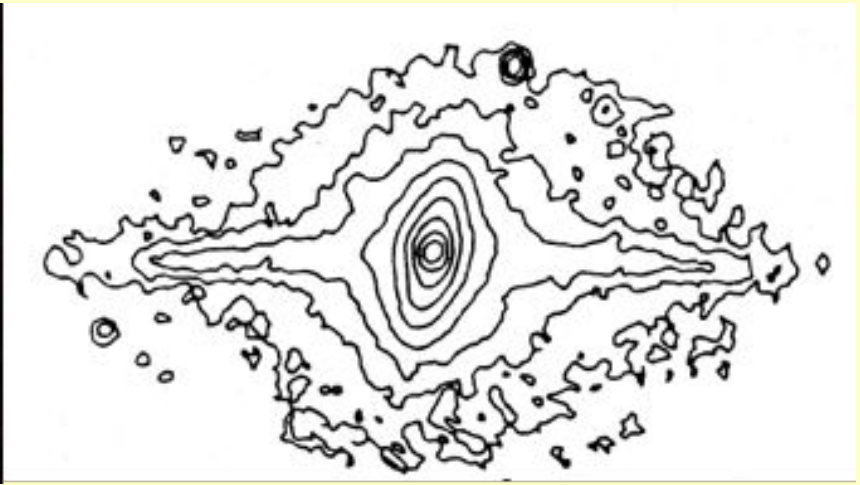
Sil'chenko & Moiseev 06
Mazzuka + 06:
the ring might be produced as resonance features by tidally induced oval distortions of the global stellar disks.



Stellar kinematics:
SAURON (Fathi 04)

Polar ring galaxies: a classical view

BTA, CCD 530x580



Reshetnikov, Hagen-Thorn & Yakovleva (1994)

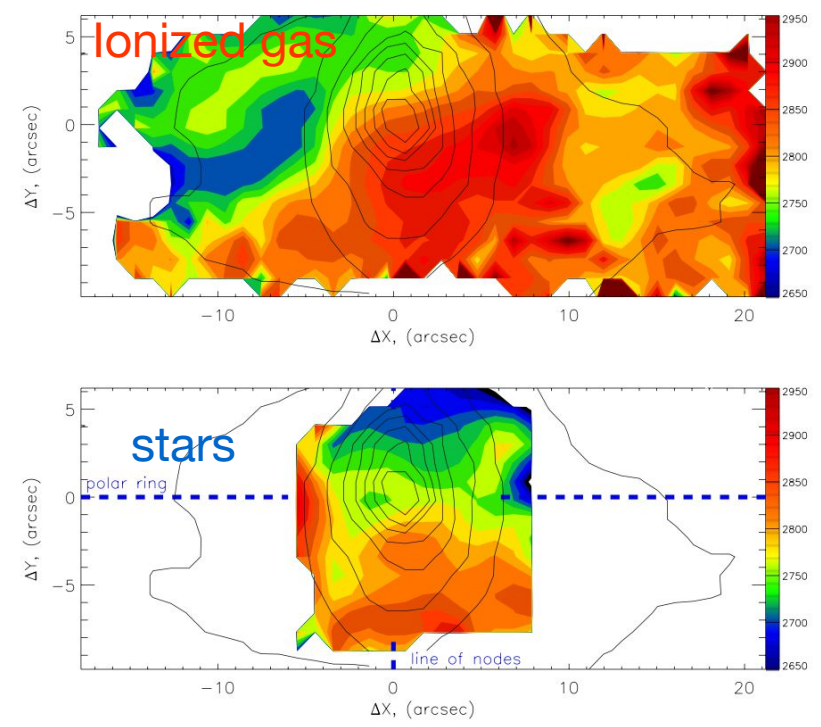
Study of the PRC objects form the catalogue by Whitmore et al (1990):

Photometric structure of discs and polar rings -> evidences of a tidal accretion scenario (Reshetnikov & Sotnikova (1997)
Kinematical confirmations of PRC candidates, testing of different hypotheses of polar structures formation (accretion from companions or filaments, colliding of two disc galaxies...)

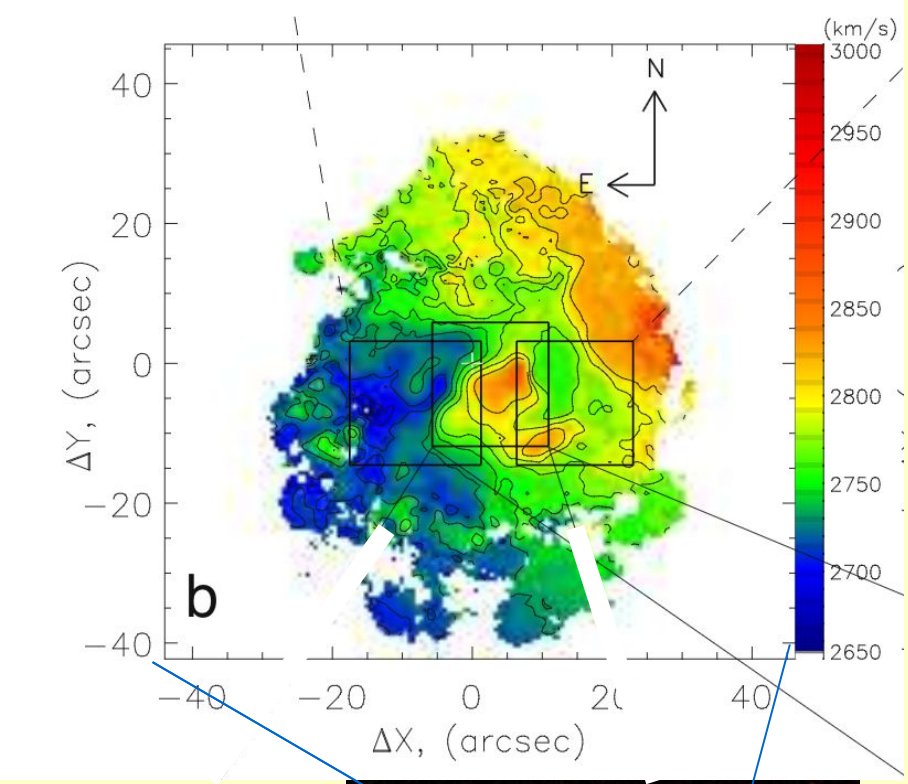
(Reshetnikov et al., Shalyapina et al.2002-2007, Merkulova et al. 2008-2013)

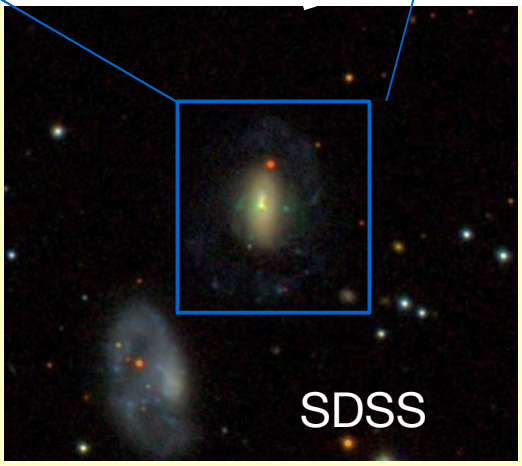
Polar ring galaxies: UGC 5600

MPFS data (Shalyapina et al. 2002)



FPI data (Shalyapina et al. 2007)

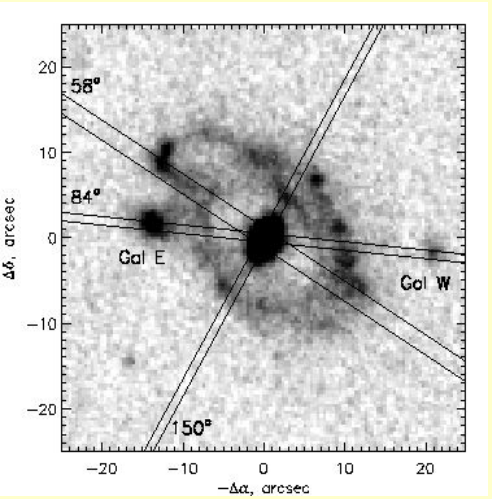


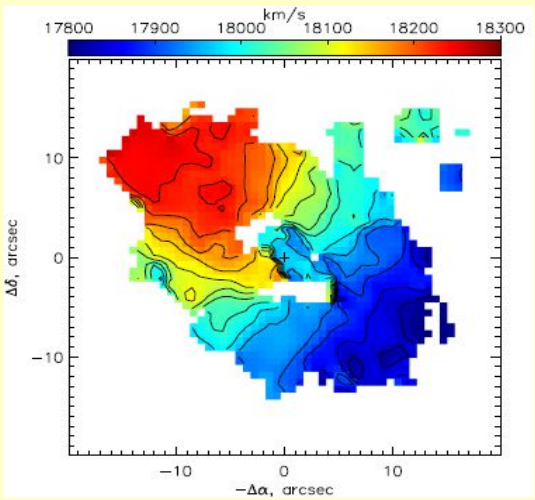


The complex structure of the galaxy:
- stellar disc
- an inner gas polar ring
- an outer gas disk.

Polar ring galaxies: new candidates Ring1 (SPRC-7)

It's ne of the largest and most distant among the confirmed PRGs

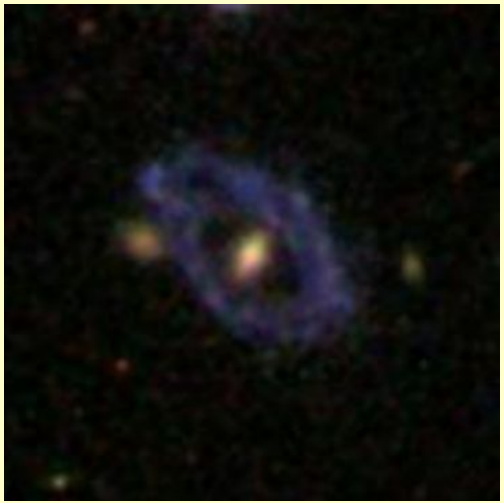




A gigant (D=50 kpc) stellar-gaseous disk inclined on Δi= 73±12º relative central S0-like host. M/L=20

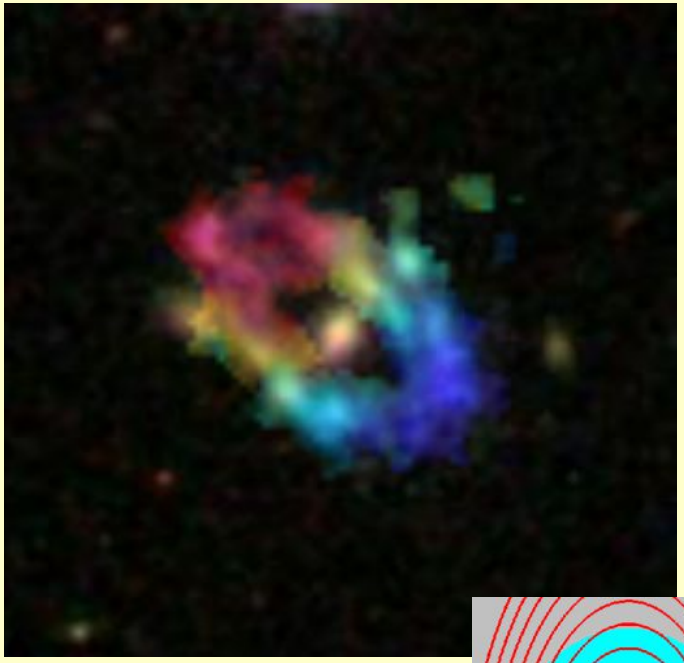
Brosch et al (2010)

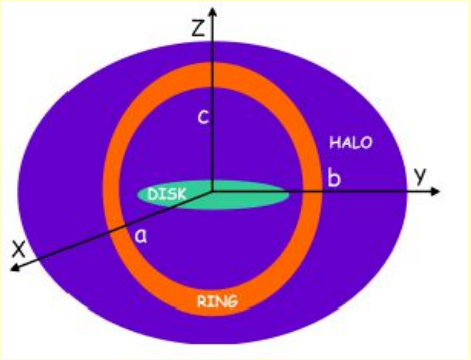
SDSS image

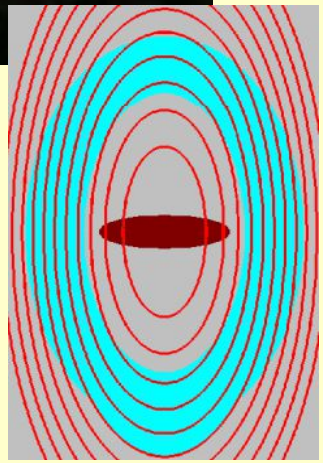


Hβ velocity field (FPI)

Polar ring galaxies: Dark halo shape

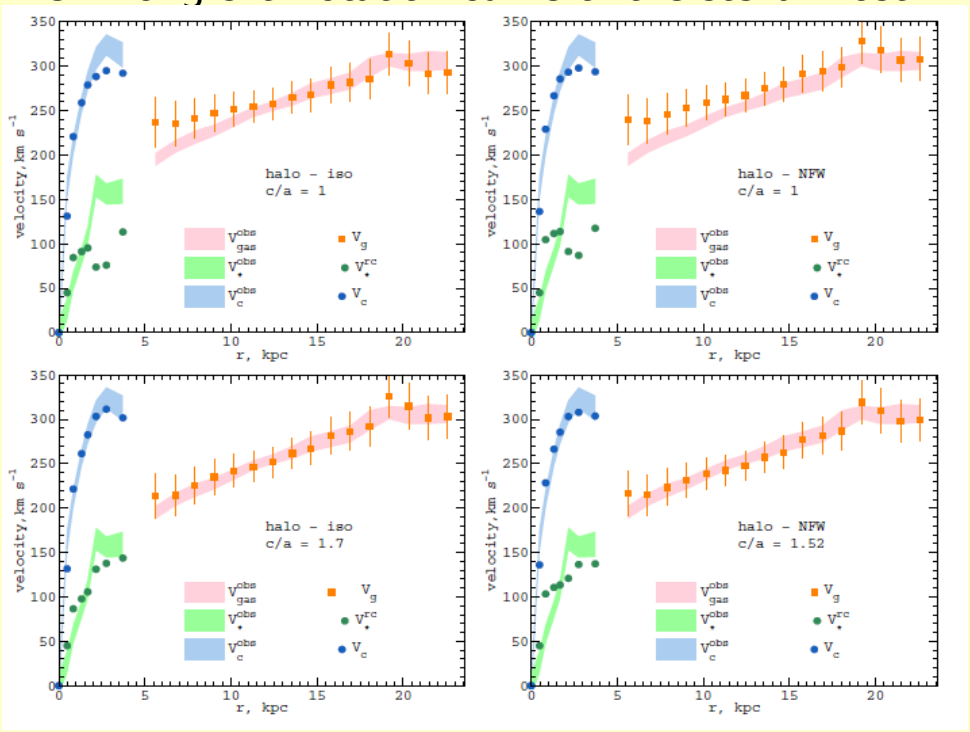






Brosch et al (2010):
A giant (D=48 kpc) stellar-gaseous disk
inlcined at Δi= 73±12º to the central S0-galaxy

FPI: ionized gas in the ring
SCORPIO-2 long-slit: rotation curve of the stellar host

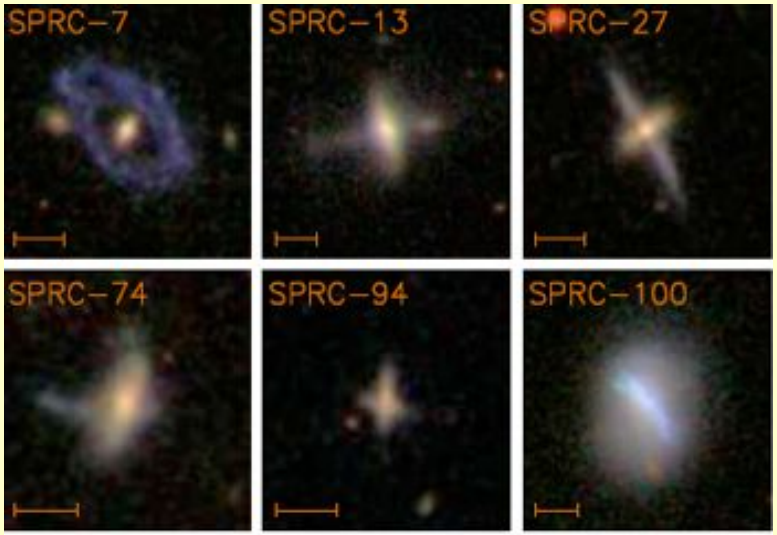


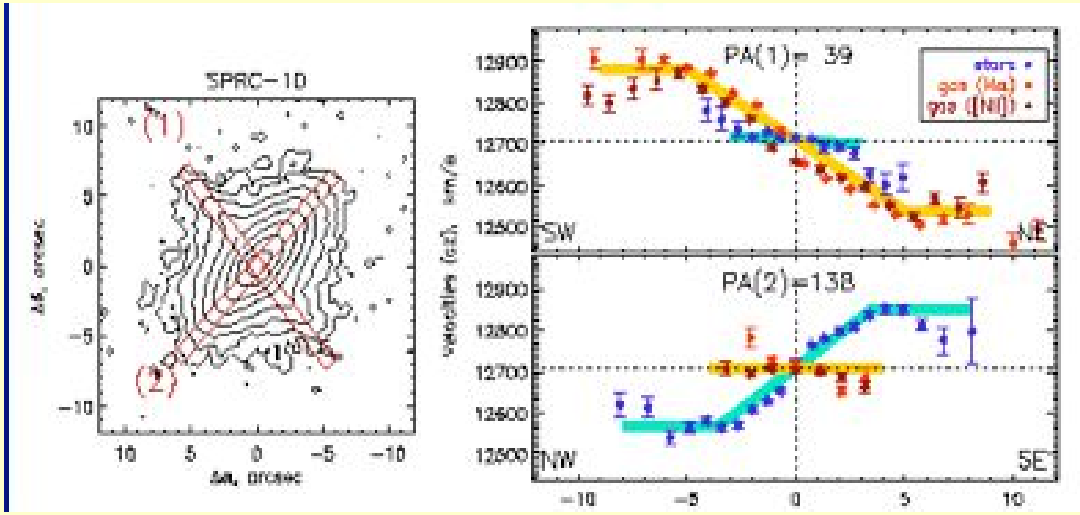
The halo is noticeably flattened to the plane of the ring (the axial ratio of 1.5-1.7 depending on the adopted model of the density distribution)

Khopersko et al (2014)

Polar ring galaxies: SPRC

Sloan-based Polar Ring Catalog (Moiseev, Smirnova, Smirnova & Reshetnikov,2011):
Inspection by eyes of ~ 40 000 candidates selected using GalaxyZoo

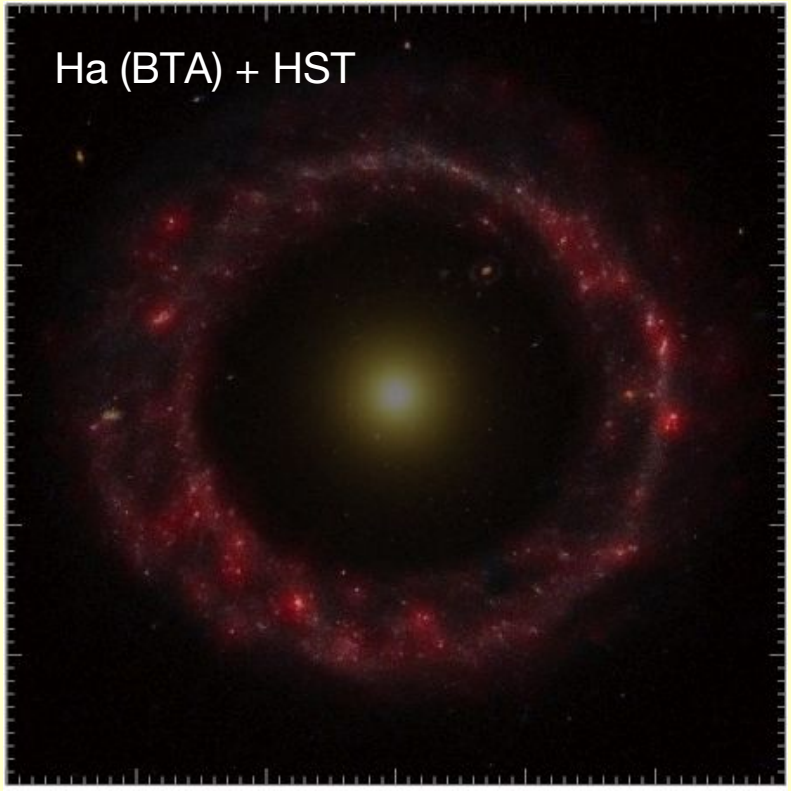


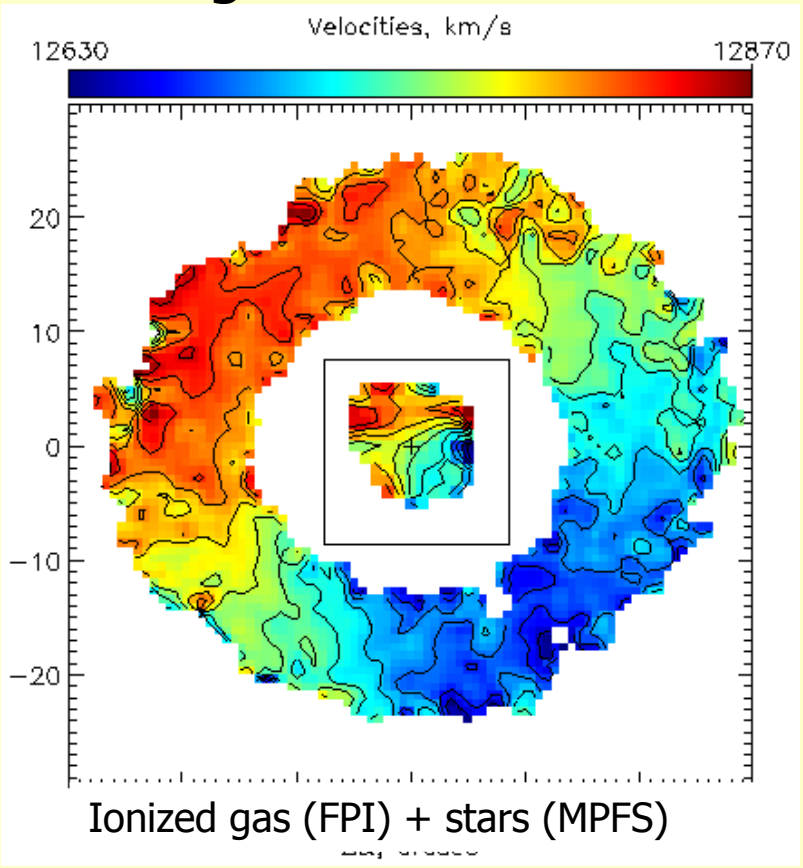


Spectral study of the new candidates in long slit and FPI mode:
- candidates confirmations
- kinematics: T-F relation, halo shape
- chemical abundance and ionization condition

=> talk by Oleg Egorov yesterday!

Hoag's object: evidence for cold gas accretion

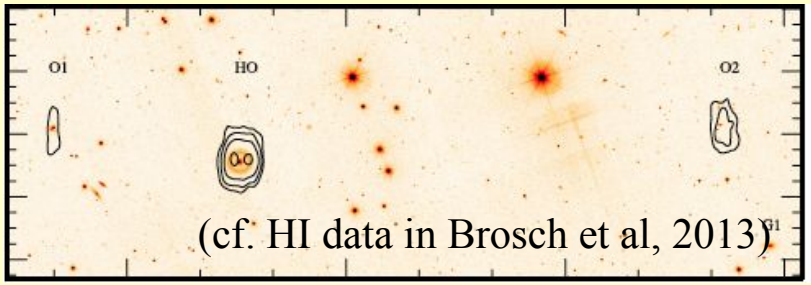




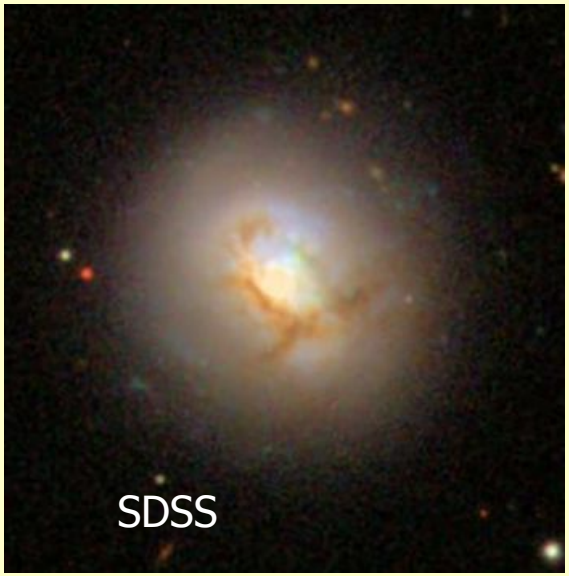
Ionized gas (FPI) + stars (MPFS)

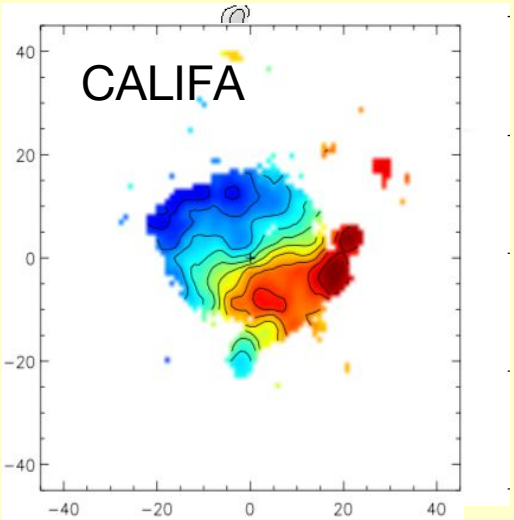
Finkelman, Moiseev, Brosch & Katkov: (2011)

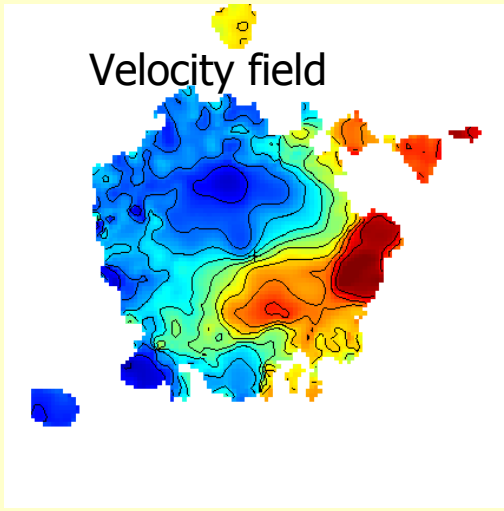
- the elliptical core formed in the early Universe (10-15 Gyr) during the monolithic dissipative gas collapse.
- A prolonged 'cold' accretion of primordial gas from the intergalactic medium formed the ring.
- the star formation started in the ring 2-4 Gyrs old.

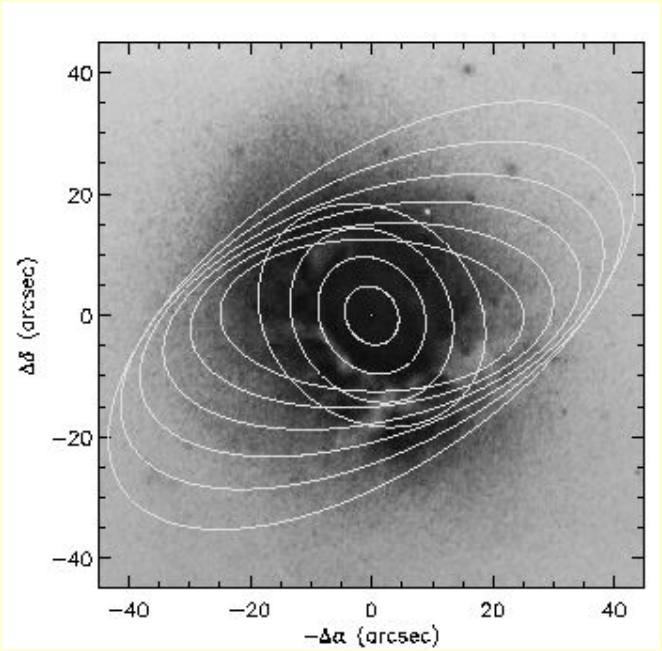


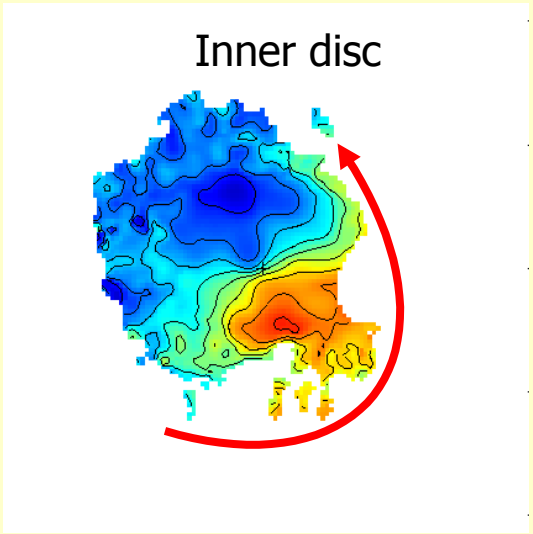
Polar ring structures in late type galaxies: Arp 212

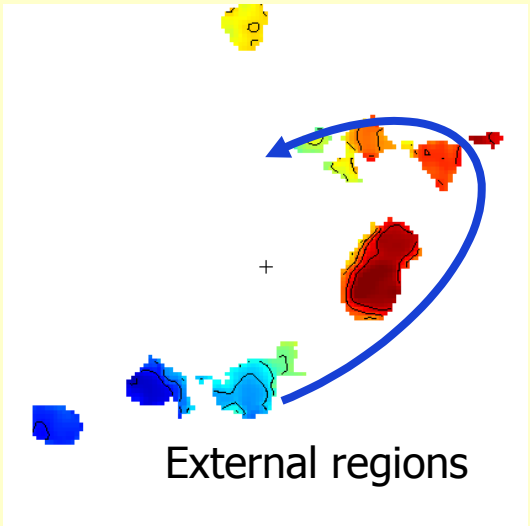






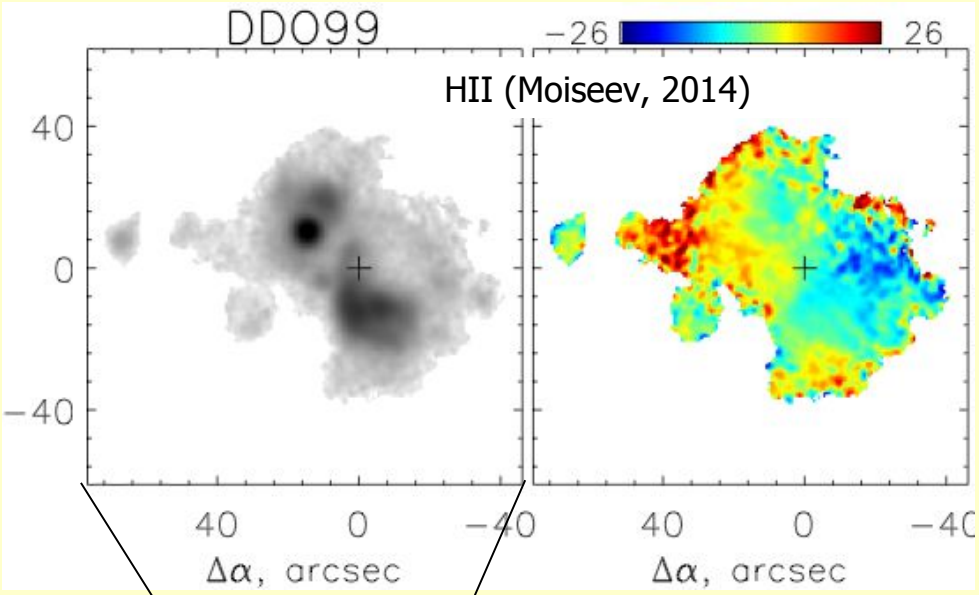


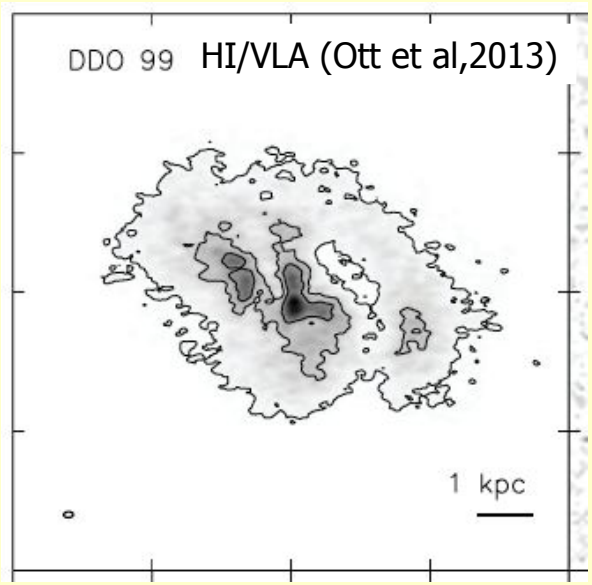


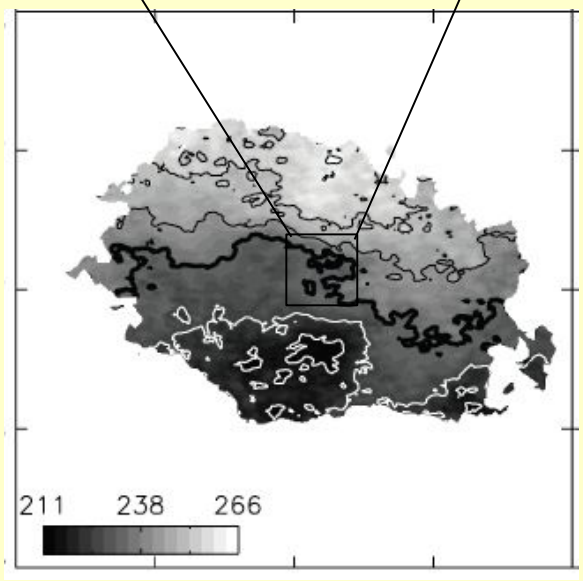


Moiseev (2008)

Polar ring structures in local dwarf galaxies





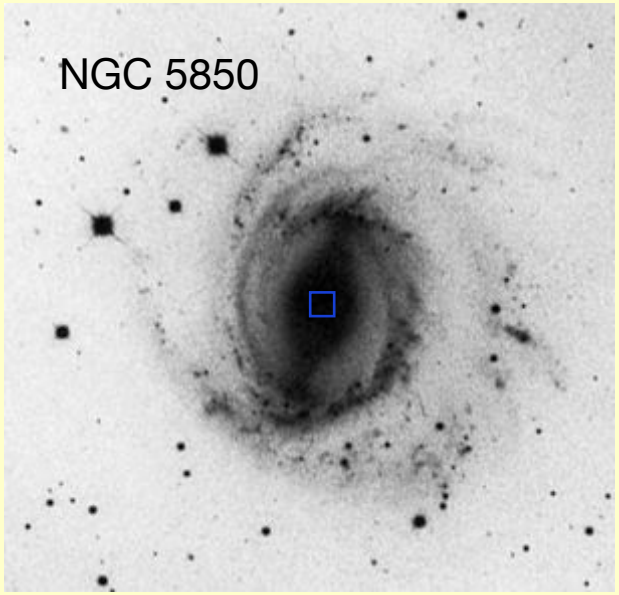


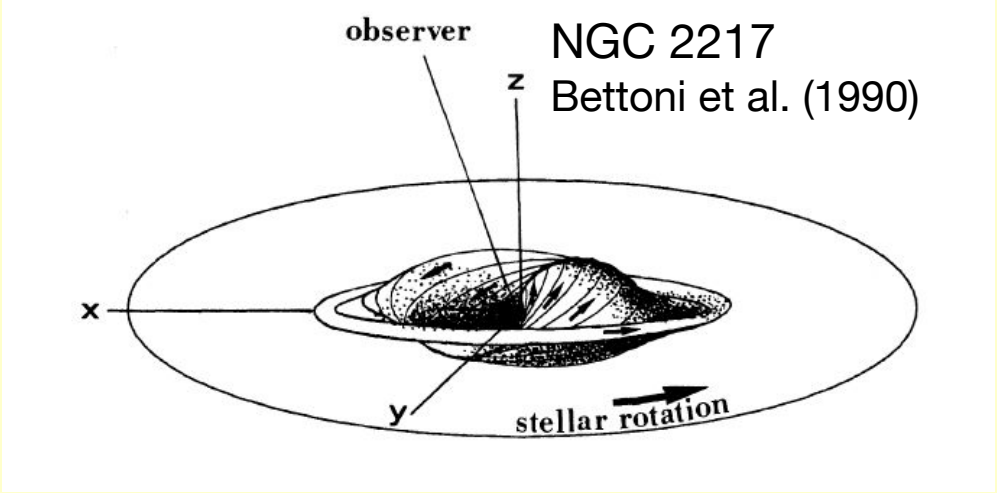
Strong warp or polar HI disc?

The HII is coplanar with the stellar disc. Is it a primordial matter or result of precession of the external structure?

Moiseev (2014): 3 inclined/polar structures among 25 local dwarf galaxies

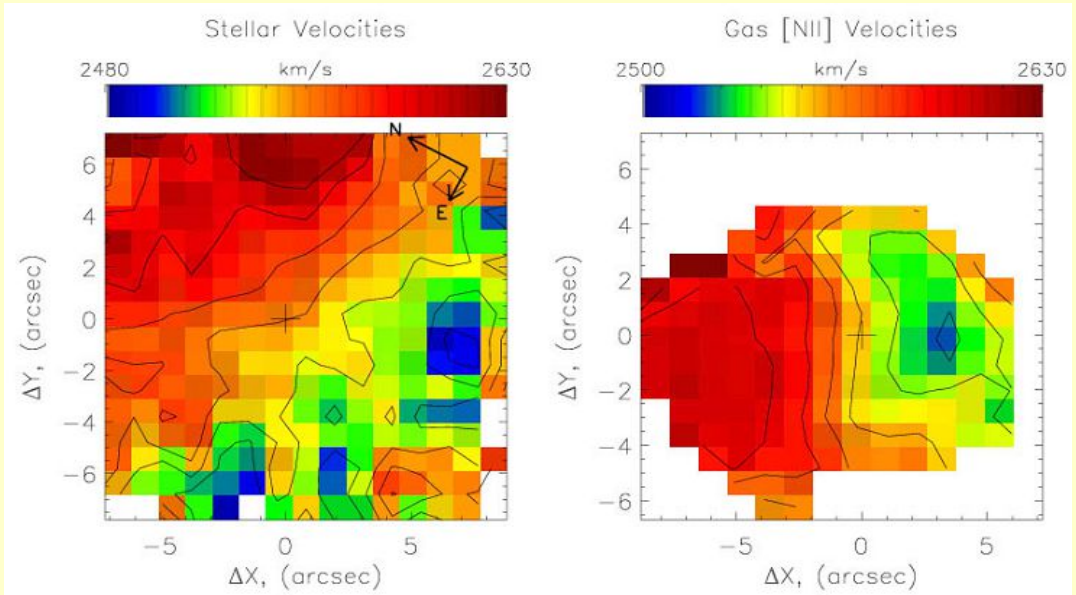
Inner polar structures

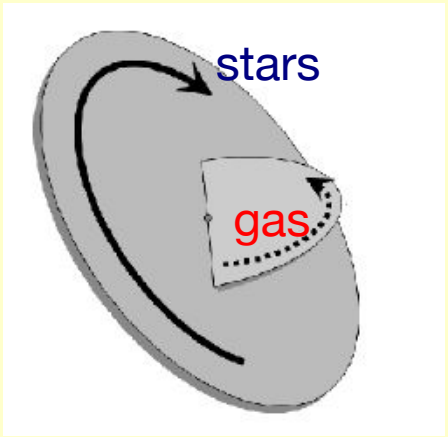




NGC 2217
Bettoni et al. (1990)

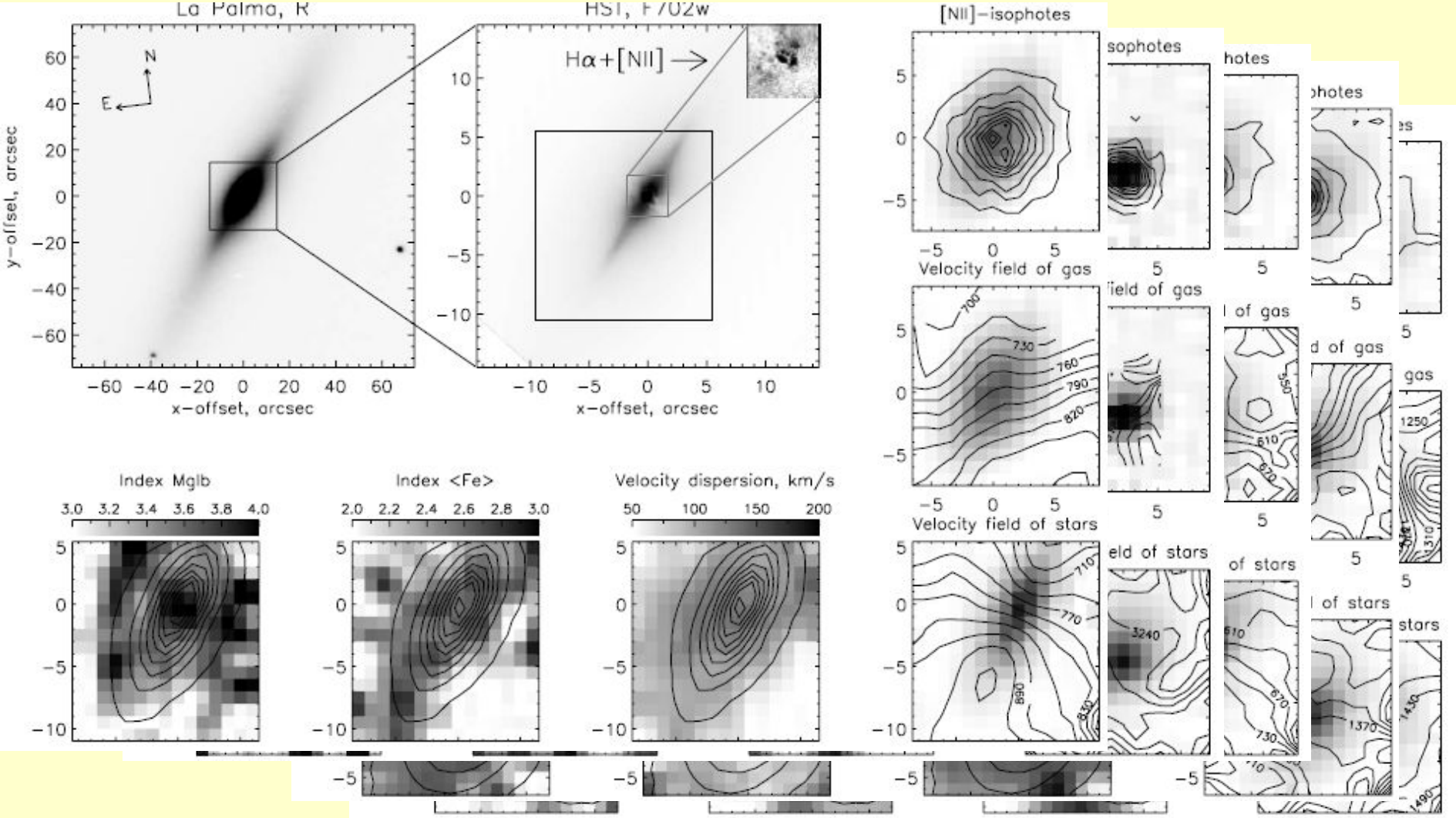
Silchenko et al. 1997: Nuclear polar ring in NGC 2841
Silchenko & Afanasiev 2000: NGC 7217





Moiseev et. (2004)

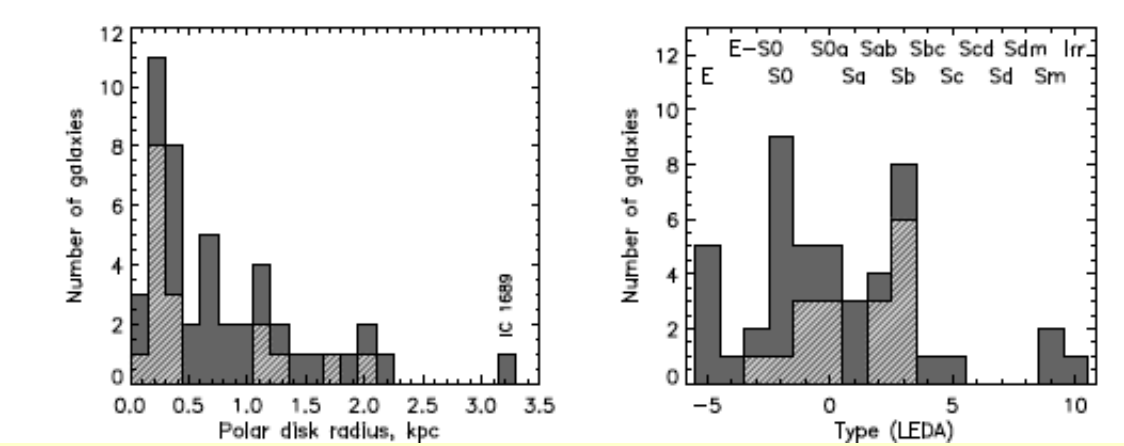
2D kinematics of S0 galaxies with circumnuclear dust lanes

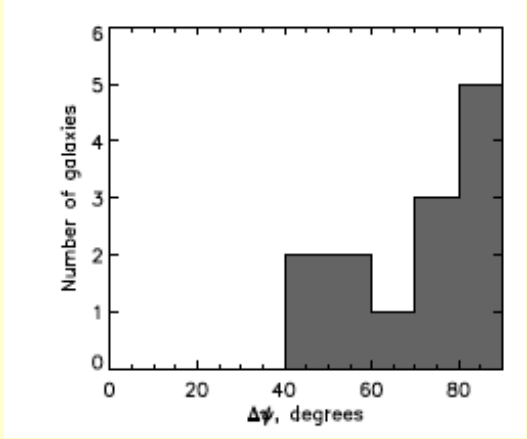


Sil'chenko & Afanasiev (2004): MPFS observations of stars and gas kinematics

Inner polar structures: sizes and statistics

Corsini et al. (2003) listed 17 galaxies where inner polar structures (IPS) were found
Moiseev (2002): 47 galaxies with confirmed IPS:
60% of described structures have been discovered or confirmed in the 6-m telescope observations

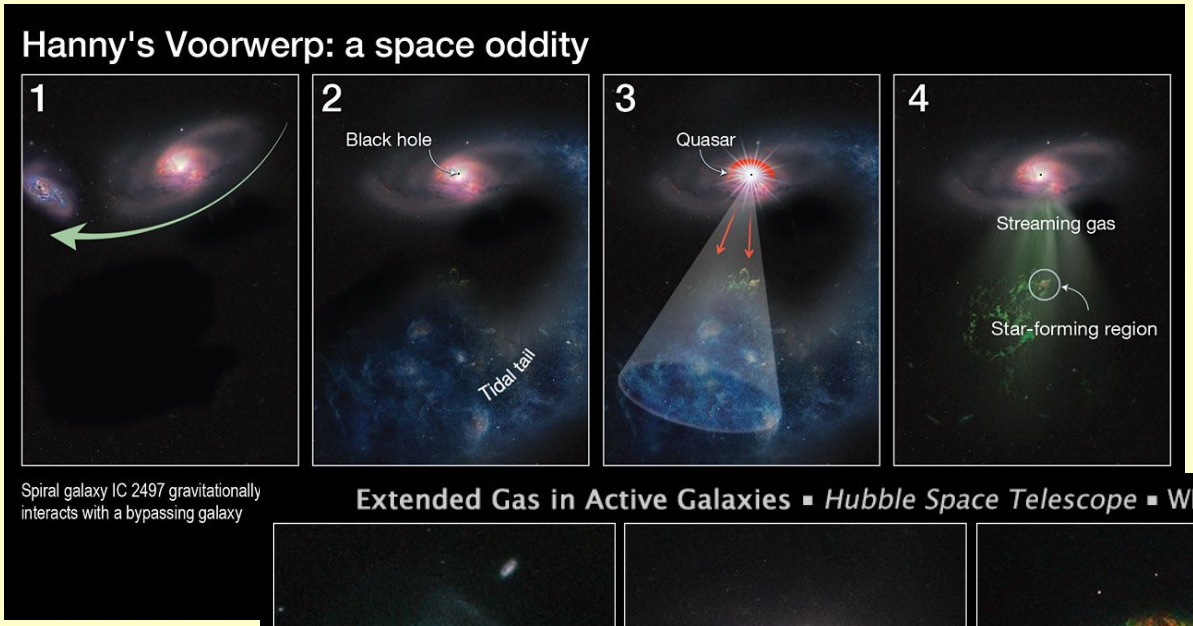


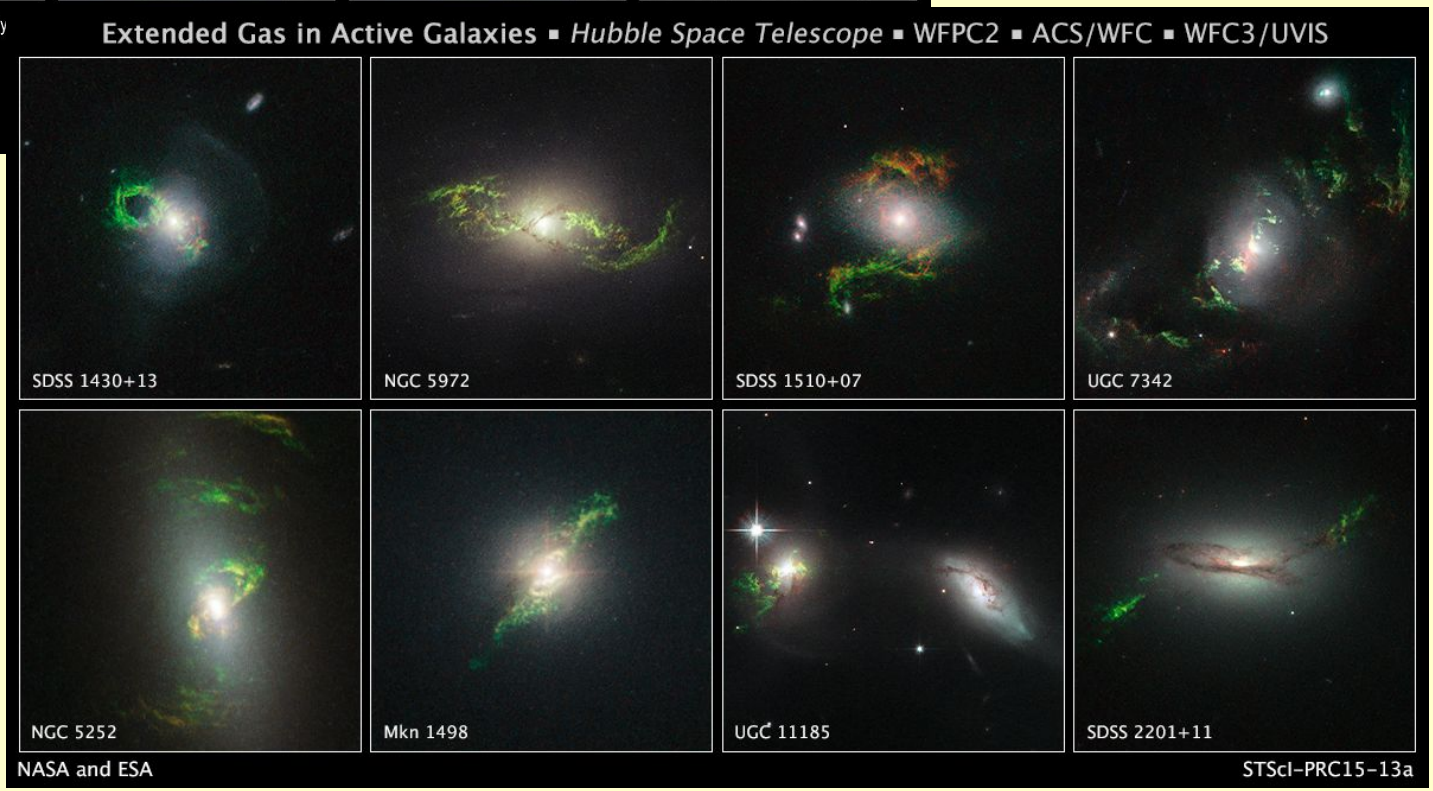


Environment effect: in 70% of galaxies reveal signs of a recent interactiond (tidal structures, counter-rotating components, etc.), pointing to the
leading role of the external environment in the for mation of these peculiar structures.

“It is as yet difficult to estimate the frequency of occurrence of circumnuclear polar disks, since our sample is composed from very heterogeneous sources ..“
=>
New paper by Olga Sil'chenko (2016, AJ, 152, 73): 10% of inner polar disk in S0 (ATLAS-3D sample)

New works and plans: emission clouds around local AGN

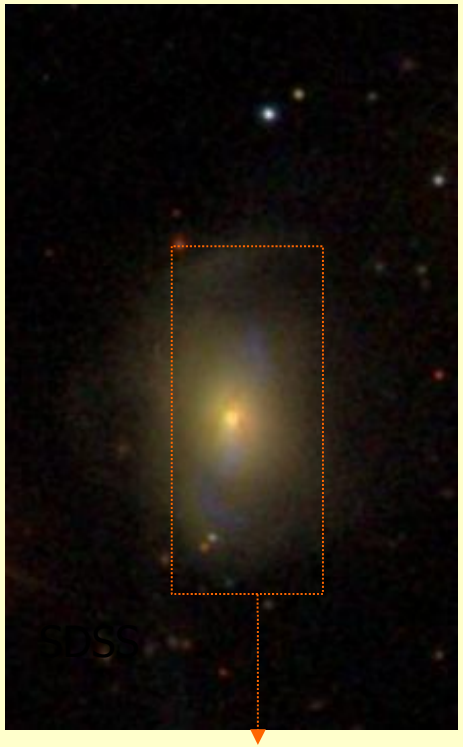




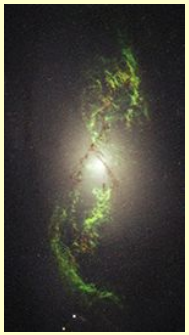
Fading AGN:
Keel et al (2012) sample.

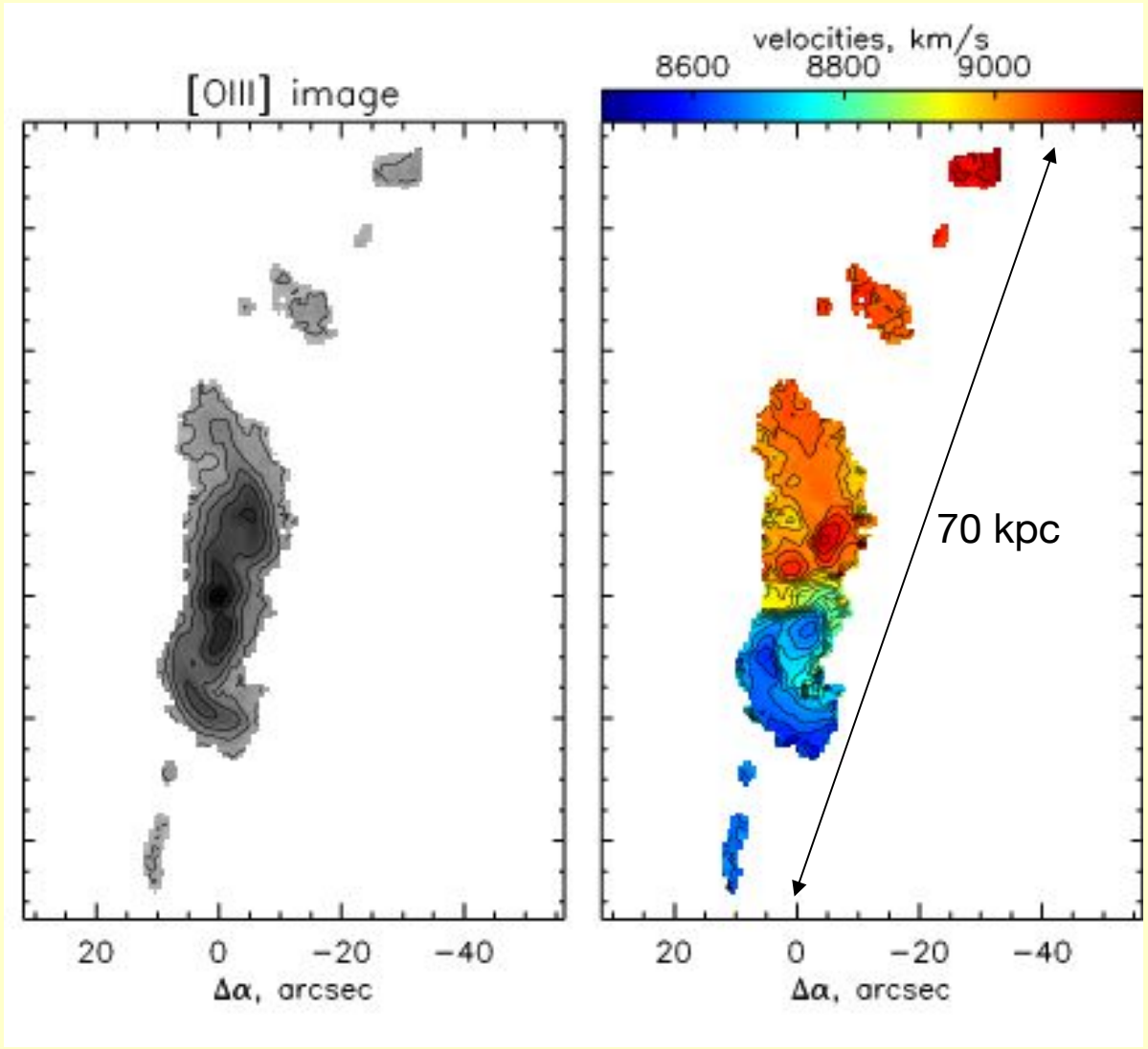
An `ionization history' in accreted external gas!

NGC 5972: the distant filaments



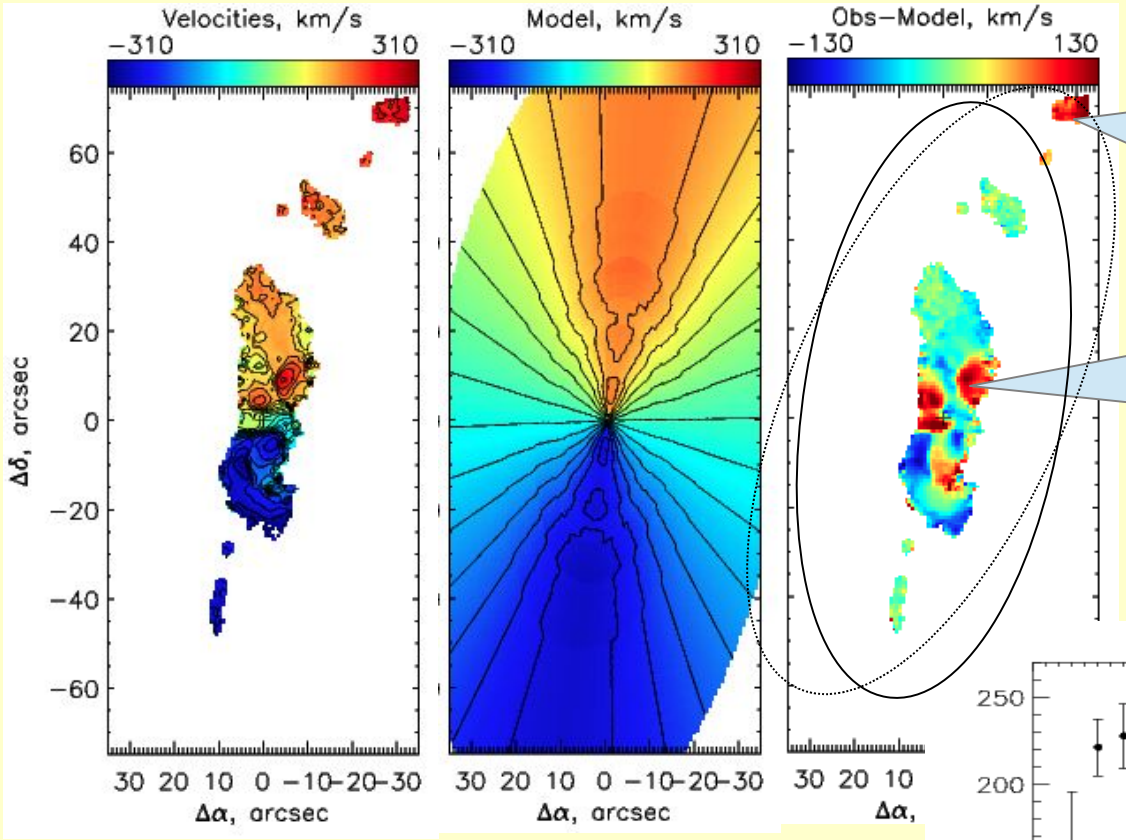
HST





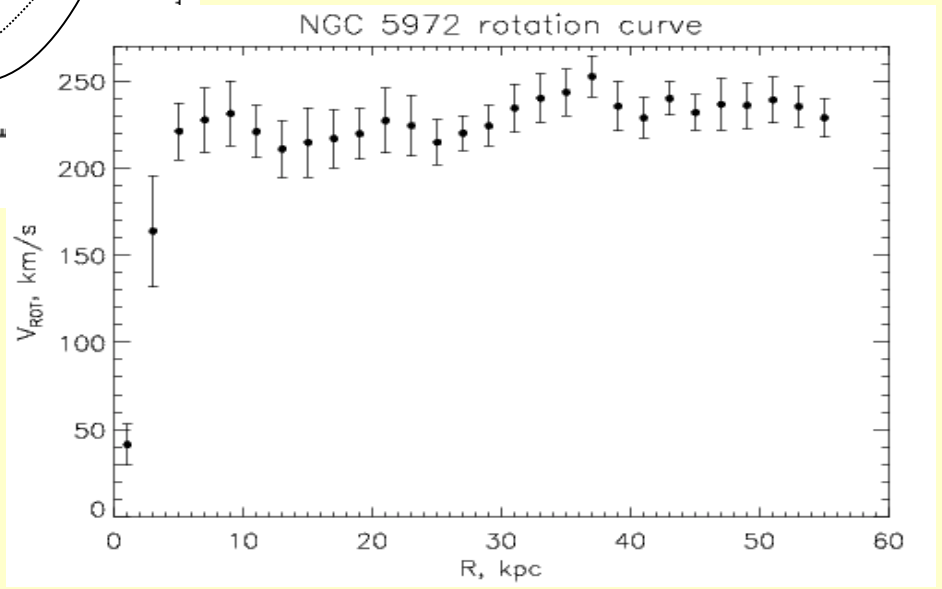
Keel et al (2015)

NGC 5972: the distant filaments



Vres=+80 km/s
or~20 km/s
for modest warp ΔPA=15-20°

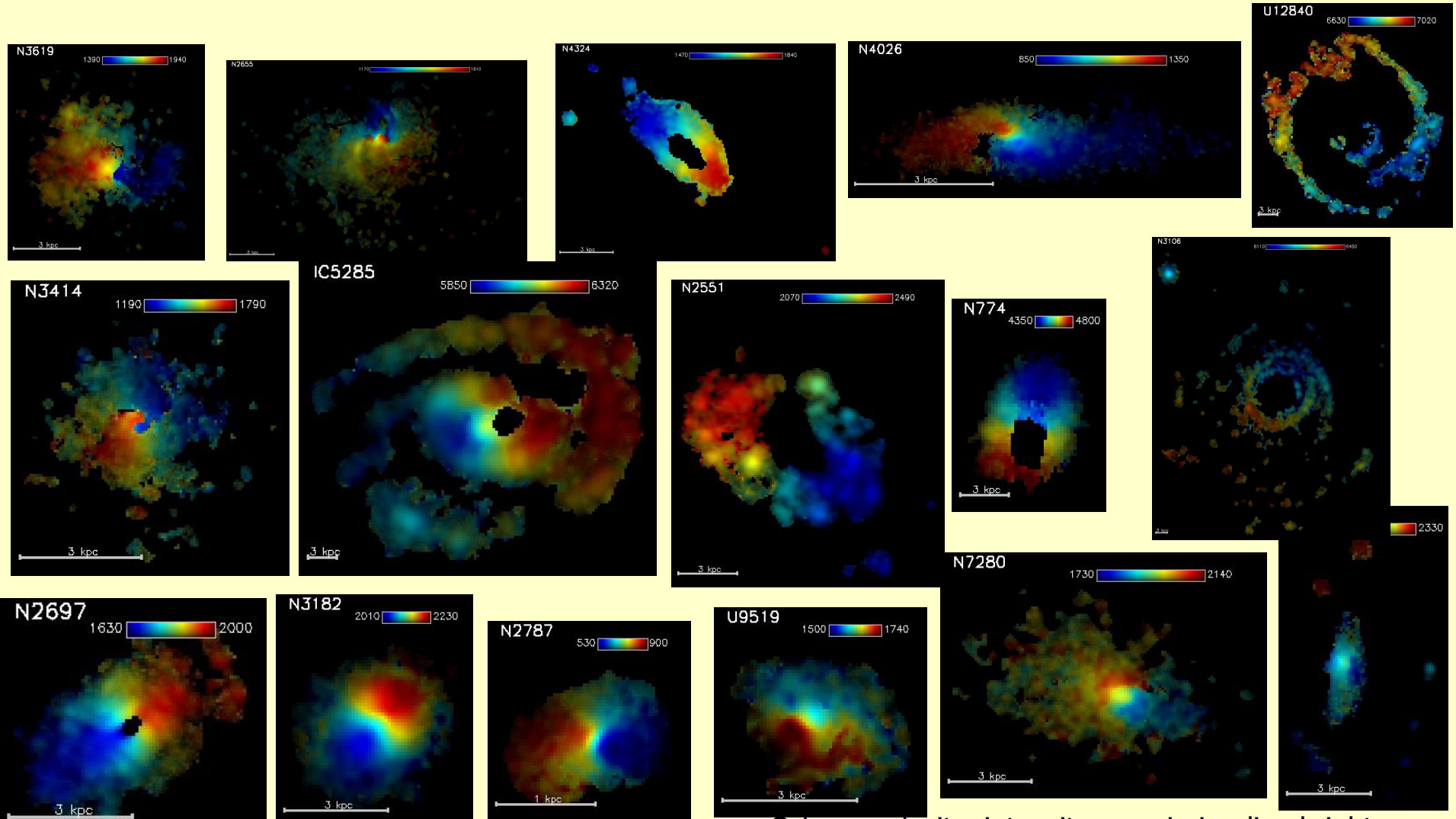
Near the nucleus:
Vres=±150 km/s
(outflow?)



Residual velocities from tiilted-rings model of circular rotating disc
Vres=±10-20 km/s

New works: external gaseous discs in S0-galaxies

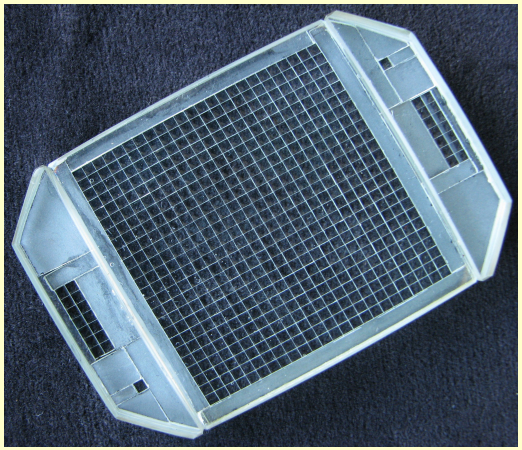
=> Olga Silchenko talk



Color = velocity, intensity = emission-line brightness

New equimpents

SCORPIO-2 IFU (20"x20' 0.7"/spaxel)

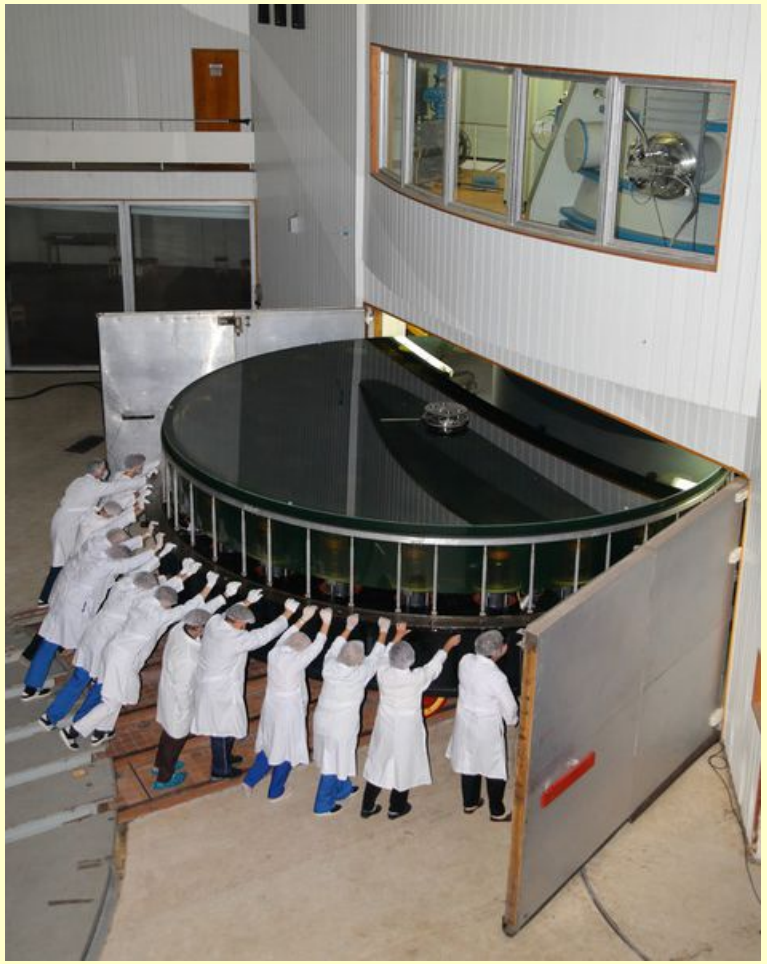


Developed by Victor Afanasiev

Tunable-filter FPI (FWHM~15 A)

SCORPIO-2 responsible astronomers:
Victor Afanasiev: vafan@sao.ru
Alexei Mosieev : moisav@sao.ru
http://www.sao.ru/hq/lsfvo/

Many thanks to the telescope and
to the scientific and technical staff!



(Moving of the 6-m mirror to the vacuum camera)